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## **The Dynamic Microstructure of Speech Production: Semantic Interference Built on the Fly**

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# The Dynamic Microstructure of Speech Production: Semantic Interference Built on the Fly

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We present 4 experiments investigating dynamic and flexible aspects of semantic activation spread during speech planning. In a semantic blocking paradigm, pictures of objects were presented in categorically homogeneous blocks consisting of semantic category members (e.g., foods), in blocks consisting of seemingly unrelated objects that could potentially be integrated into a common theme (e.g., fishing trip), or in heterogeneous blocks consisting of entirely unrelated objects. In Experiment 1 we observed a classic semantic interference effect for the categorically homogeneous condition but no effect for the thematically homogeneous condition. In Experiment 2 the blocks were preceded once by visually presented title words. When titles were presented that referred to the semantic category or theme of the block, interference was observed not only in the categorically homogeneous condition but also in the thematically homogeneous condition. The ad hoc semantic interference effects for thematic relations were replicated with a different set of materials in Experiments 3 and 4. These observations reveal the dynamic nature of the speech production system, shaped by context and formations of flexible ad hoc categories and semantic relations.

**Keywords:** speech production, lexical interference, semantic context effects, ad hoc relations

Semantic contexts can strongly modulate the speed and accuracy of speaking. A major source of empirical support for this central assumption in language production stems from studies investigating semantic interference effects in picture naming. Providing a semantic context, for instance by presenting a related distractor word accompanying a to-be-named picture in the picture-word interference (PWI) paradigm (e.g., Glaser & Glaser, 1989; Lupker, 1979; Schriefers, Meyer, & Levelt, 1990) or a semantically homogeneous composition of objects in the semantic blocking paradigm (e.g., Belke, Meyer, & Damian, 2005; Damian, Viglocco, & Levelt, 2001; Kroll & Stewart, 1994), slows down naming latencies compared to unrelated distractors or heterogeneous blocks of unrelated objects.

Although interference effects are well attested for categorical relations, evidence for similar effects for other, noncategorical semantic relations is scant. Specifically, distractor words that are associatively<sup>1</sup> related to the target induce no effects or facilitation (see e.g., Alario, Segui, & Ferrand, 2000; Bölte, Jorschick, & Zwitterlood, 2003; Costa, Alario, & Caramazza, 2005 [for part-whole relations]; La Heij, Dirks, & Kramer, 1990; Lupker, 1979). This dissociation seems to suggest that only specific types of

semantic relations, namely, categorical relations, yield context effects that result in lexical competition.

However, Abdel Rahman and Melinger (2007) have recently demonstrated interference for semantic associates in the semantic blocking paradigm. When associatively related items from different categories are presented within a common blocking context that interrelates these items in a meaningful way (e.g., semantic associates of the thematic context “garden”: *slug*, *gardener*, *rake*, etc.), naming latencies are slowed relative to semantically heterogeneous blocks in a similar way as classically observed for categorical relations. In contrast, when the same associates are presented as distractor words within a PWI situation, facilitation has been observed. Our account for these differential effects of associative relations is that in the blocking paradigm, lexical competition is enhanced by the coactivation of a whole cohort of interrelated lexical entries (e.g., all members of the blocking context “garden” are coactivated, amplifying lexical competition). This enhanced lexical competition is stronger than the concomitant context-induced conceptual facilitation (see Abdel Rahman & Melinger, 2009b), resulting in net interference effects. In contrast, two associates presented in isolation in the PWI paradigm tend to have a one-to-one relation, not activating an interrelated lexical

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<sup>1</sup> Semantic associates are often defined either as words that are spontaneously called to mind by another word (e.g., Nelson, McEvoy, & Dennis, 2000; Schulte im Walde, Melinger, Roth, & Weber, 2008) or as words that co-occur often in texts (Miller, 1969; Spence & Owens, 1990). Because we are interested in dynamic changes to evoked semantic relations, we use *association* quite loosely to refer to any nontaxonomic relation. Associate relations, according to this usage, can index traditional semantic relations such as holonymy and meronymy, as well as nonclassical features that are tied to a concept on the basis of experience.

cohort. The resulting interference is not strong enough to overcome concomitant conceptual facilitation.

Associatively induced semantic interference effects in the blocking paradigm suggest that meaningful contexts in which an utterance is produced (i.e., the other words that are produced contemporaneously or even other objects or thoughts that are copresent while speaking) strongly modulate the conceptual and lexical activation patterns induced by semantic relations that are stored in long-term memory. Here, we go one step further and test the scope and limits of such dynamic context effects. Specifically, we investigate whether ad hoc category formations, integrating seemingly unrelated objects, modulate the pattern of semantic interference effects in a flexible way.

Up until now the vast majority of research on semantic contexts modulating the time course of speech production has focused on classic, predefined semantic relations that are stored in long-term memory (PWI: Damian & Martin, 1999; Glaser & Döngelhoff, 1984; Jescheniak, Schriefers, & Hantsch, 2001; Lupker, 1979; Rosinski, 1977; Schriefers et al., 1990; Starreveld & La Heij, 1995; Underwood, 1976; see MacLeod, 1991, for a review; semantic blocking: Belke, 2008; Belke et al., 2005; Damian et al., 2001; Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006). For instance, semantic category members such as *horse* and *cow* have a taxonomic relation specified by their group membership ("animals") and a high statistical correlation between co-occurring semantic features (e.g., four legs, herbivores, etc.). In this sense, categorical relations are hard wired, well established in memory, immediately evident, fast, and presumably automatically activated (e.g., Carr & Dagenbach, 1990; Grill-Spector & Kanwisher, 2005; Heil, Rolke, & Pecchinenda, 2004; Kiefer, 2007; Thorpe, Fize, & Marlot, 1996). However, taxonomic organization does not exhaustively describe semantic memory organization. Semantic memory is also characterized, for example, by associations between concepts grounded in our experiences (e.g., Barsalou, 1983, 1993, 2008, 2009; Goldstone, Steyvers, Spencer-Smith, & Kersten, 2000). Despite support for alternative organizations of semantic memory, evidence to suggest that non-categorical relations impact the time course of speech production in an analogous fashion to taxonomic structure is limited (Abdel Rahman & Melinger, 2007; Aristei, Melinger, & Abdel Rahman, 2010).

Here we attempt to further the investigation of how noncategorical relations can impact production processes by exploring context effects from a different perspective. We test whether interference between seemingly unrelated items can be induced by ad hoc context modulations and flexible category formations built on the fly.

### The Formation of Ad Hoc Relations and Categories

Ample evidence suggests that concepts and categories can be flexibly formed and shaped by context modulations or situational goals (Barsalou, 1983, 1985, 1991; Vallée-Tourangeau, Anthony, & Austin, 1998; for recent reviews, see Barsalou, 1993, 2007). For instance, although the musical instrument *piano* is typically classified with taxonomic sisters such as *trumpet* and *harp*, it might alternatively form a better suited category with objects such as *washing machine* and *wardrobe* in the context of moving heavy furniture (e.g., Barclay, Bransford, Franks, McCarrell, & Nitsch,

1974). Barsalou (1982) reported faster extraction of object features (e.g., flammability as an attribute of newspapers) in relevant contexts (e.g., building a fire) than in neutral contexts, supporting the notion that access to semantic features is not fixed but rather dynamic and sensitive to context. Similarly, Chrysikou (2006) has demonstrated rapid ad hoc construction of categories during problem solving (e.g., using shoes as tools for hammering).

The discussed reports of concept and category modulations suggest a high degree of flexibility and situated dynamic adaptations within the semantic system. Categories can be formed and ignored as the respective context or goal requires. Thus, established categories as well as novel or less established categories can shape conceptualization, depending on the situation. According to Barsalou (2007), different aspects of knowledge associated with a concept are activated according to the specific situational requirement or goal, yielding established relations that are entrenched in long-term memory or, alternatively, ad hoc associations between concepts that are much less established in long-term memory.

The question addressed here is whether such conceptual dynamics exert an influence on the activation pattern during lexicalization. Can the time course of speech production be modulated by ad hoc categories integrating objects that are—in the classic sense—neither categorically nor associatively related? As discussed above, semantic context effects have almost exclusively been studied with hard-wired relations stored in long-term memory. It is therefore unclear whether ad hoc relations yield comparable effects—and if so, under which conditions. Thus, we investigate whether the formation of thematic categories induces semantic interference effects typically observed for classic taxonomic-categorical relations in the blocking paradigm. Thematic categories are defined here as integrating semantically dissimilar items (that are neither categorically nor associatively related in the classic sense) that belong to a common event or theme, thus forming a spatially and/or temporally coherent entity, crossing taxonomic boundaries (e.g., Kimball, Muntean, & Smith, 2010; Kurtz & Gentner, 2001; Raisig, Welke, Hagendorf, & van der Meer, 2007; van der Meer, 1991; Wisniewski, Imai, & Casey, 1996; Yeh & Barsalou, 2006).

For instance, objects like *stool*, *knife*, *bucket*, and *river* have no obvious categorical or associative relations at first sight; their potential relation is opaque. As a baseline condition, in Experiments 1 and 3A we tested, with different materials, whether participants would spontaneously form congruent categories for such objects in the blocking paradigm, a behavior that should be reflected in interference effects. On the basis of the empirical evidence discussed above, we did not expect interference effects for thematic relations in these experiments.

In Experiments 2 and 4, we tested whether the same objects would induce semantic interference when a different group of participants were prompted to form ad hoc thematic categories for these items. We did so by providing a title word before the blocks started. This word interrelated the objects in terms of a common theme: The above objects can form a coherent category of things present on a fishing trip. Furthermore, Experiment 3B tested for interference effects with a within-subjects design. We tested whether title-induced interference effects for thematic relations would be observed even when the objects were repeatedly named before in thematic blocks, in the absence of interference effects.

## Experiment 1

In this experiment, pictures of objects were repeatedly named in three blocking conditions. The objects within a block could be categorically related (categorically homogeneous condition; e.g., *coffee, milk, rice*, etc.) or unrelated (heterogeneous condition; e.g., *coffee, mat, scale*, etc.). In a third condition the blocks consisted of seemingly unrelated objects that were neither categorically nor associatively related (e.g., *coffee, knife, bucket*, etc.; see Appendix A). The objects could, however, potentially be integrated into a common theme or topic (e.g., a fishing trip). Thus, although the relation was not obvious, the objects here were not entirely unrelated. Therefore, in order to avoid obvious relations between the objects, care was taken that none of them (or their visually depicted version) was a prototypical exemplar for the respective theme (for the above example, objects like *fish* or *fishing rod* were not presented). The experiment tested whether such opaque thematic relations could, by themselves and spontaneously, induce semantic interference effects comparable to those found for stable and established categorical, or associative, relations.

## Method

**Participants.** Sixteen women and eight men, aged 19 to 45 years ( $M = 23$ ), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All participants were native German speakers and reported normal or corrected-to-normal visual accuracy and normal color vision.

**Materials.** The target picture set consisted of 25 color photographs of common objects from five semantic categories (“bins,” “locations,” “tools,” “food,” and “furnishings”). The objects could be recombined to form 10 orthogonal sets of unrelated objects from different categories. Five sets served as the heterogeneous blocking condition. The objects in the other five sets were also seemingly unrelated, semantically and visually dissimilar, and drawn from different semantic categories. They could, however, potentially be interrelated by explicitly drawing participants’ attention to a common theme or topic that interrelated the objects in a meaningful way (see Appendix A). None of the objects was a prototypical member of the respective scene or thematic category. Within one block of trials, the pictures could either be presented together with other members of the same semantic category (categorically homogeneous condition), together with seemingly unre-

lated objects from different categories that could be related as thematic category members (thematically homogeneous condition), or together with categorically and thematically unrelated objects (heterogeneous condition). All photographs were scaled to  $3.5 \times 3.5$  cm.

**Procedure and design.** Each trial began with a fixation cross displayed in the center of a light gray screen for 0.5 s. Then a picture was presented for 2 s, followed by a blank screen for 1 s. Naming latencies were measured with a voice key during the entire duration of picture presentation. After the naming response was registered, the picture disappeared. Participants were instructed to name the pictures as fast and accurately as possible. Prior to the experiment participants were familiarized with the pictures and their names as follows: All photographs were presented in random order on the screen, and participants were asked to name each picture. If necessary, they were corrected, or the picture name was provided by the experimenter. After this procedure was repeated twice, participants were given a printed color sheet with all pictures and their names printed below. Then, 15 short experimental blocks (sets) of 30 trials each were carried out. Each set consisted of five pictures presented repeatedly across six repetition cycles. The 15 sets were presented blocked by condition (categorically homogeneous, thematically homogeneous, heterogeneous), with the order of the conditions counterbalanced across participants. The order of the different sets within each condition was also counterbalanced across participants such that every participant had a different order of sets within each condition. The order of picture presentation within each set was randomized individually for each participant, separately for each repetition. The whole session with 450 trials lasted about 30 min.

## Results and Discussion

Table 1 presents the mean reaction times (RTs) for correct naming trials, standard errors, and mean percentages of errors in the three blocking conditions, separately for the six stimulus repetitions, and collapsed across Presentations 2 to 6. Figure 1 depicts the response latencies for the three blocking conditions across all six stimulus presentations. Trials with incorrect naming, stuttering, mouth clicks, or vocal hesitations were discarded from the analysis (5.3%). All analyses of variance (ANOVAs) were calculated with

Table 1  
Descriptive Data for the Semantic Blocking Conditions and Repetitions in Experiment 1

Repetition	Categorically homogeneous			Thematically homogeneous			Heterogeneous		
	RT	SE	Err	RT	SE	Err	RT	SE	Err
1	730	11.6	6.7	722	12.4	6.0	731	16.8	5.2
2	654	12.5	3.0	635	8.6	2.0	636	10.6	2.2
3	640	10.2	2.2	626	10.8	1.0	626	9.1	0
4	640	11.8	1.8	621	8.6	0.8	618	9.1	1.3
5	630	11.1	1.8	617	11.2	1.3	618	8.4	.7
6	626	8.3	1.5	623	11.2	1.5	613	10.3	1.0
Mean of 2–6	638	10.8	2.1	624	10.1	1.3	622	9.5	1.0

*Note.* Mean naming latencies (reaction time [RT], in milliseconds), standard errors of the mean (SE), and mean percentage of errors (Err) are shown for the semantic blocking conditions and repetitions in Experiment 1.

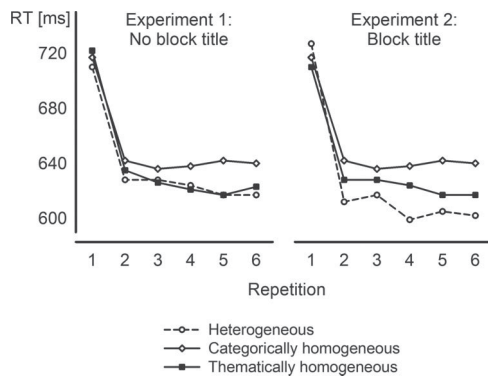


Figure 1. Mean blocking effects, separately for the six object repetitions, in Experiments 1 and 2. RT = reaction time.

participants ( $F_1$ ) and items ( $F_2$ ) as random variables.<sup>2</sup> This procedure was conducted in all experiments presented here. The error rates (see Table 1) were low and mirrored the RT effects in the blocking conditions. Errors were therefore not analyzed further.

Mean RTs were submitted to ANOVAs with the within-subjects factors semantic blocking (categorically homogeneous, thematically homogeneous, heterogeneous) and repetition (six levels). There was a trend for semantic blocking in the participants analysis,  $F_1(2, 46) = 2.5$ ,  $MSE = 3,083$ ,  $p = .09$ , and the effect reached significance in the items analysis,  $F_2(2, 48) = 3.6$ ,  $MSE = 3,551$ ,  $p < .05$ . There was also a main effect of repetition,  $F_1(5, 115) = 117.7$ ,  $MSE = 1,764$ ,  $p < .001$ ;  $F_2(5, 120) = 73.1$ ,  $MSE = 5,585$ ,  $p < .001$ , indicating faster RTs when the objects were named repeatedly. Though the interaction between blocking and repetition was not significant here ( $F_s < 1$ ), it has repeatedly been demonstrated in the semantic blocking paradigm that interference effects develop over time and are typically not observed for the first picture presentation (see Abdel Rahman & Melinger, 2007; Belke et al., 2005; Damian et al., 2001). Therefore, we conducted additional analyses on data collapsed across Presentations 2 to 6, excluding the first picture presentation. Because we were interested mainly in the presence of semantic interference effects, we confined all further analyses in the present and all subsequent experiments to the collapsed Presentations 2 to 6. These analyses revealed a main effect of semantic blocking,  $F_1(2, 46) = 3.6$ ,  $MSE = 523$ ,  $p < .05$ ;  $F_2(2, 48) = 3.6$ ,  $MSE = 797$ ,  $p < .05$ , indicating that the semantic interference effects stabilized after the first stimulus presentation. Planned comparisons revealed an effect of semantic blocking for categorical relations,  $F_1(1, 23) = 5.3$ ,  $MSE = 1,119$ ,  $p < .05$ ;  $F_2(1, 24) = 6.2$ ,  $MSE = 1,254$ ,  $p < .05$ , but not for thematic relations ( $F_s < 0.6$ ).

This experiment was conducted to assess the effects of categorical and noncategorical thematic relations for the present material in the blocking paradigm. For the categorically homogeneous condition, we replicated the classic increase of RTs relative to the semantically heterogeneous condition. In contrast, a comparison between the thematic and heterogeneous condition revealed very similar naming latencies and no statistical difference between conditions. Thus, robust semantic interference effects are observed for categorical relations but not for potential, yet unrealized, thematic relations.

Even though objects that belong to a common semantic context or frame can induce interference effects in the semantic blocking paradigm if they are associatively related (e.g., *bee* and *honey*; context: “apiary”; Abdel Rahman & Melinger, 2007), a potential thematic relation between otherwise unrelated objects (e.g., *knife* and *coffee*; context: “fishing trip”) does not appear to induce a comparable effect. This finding corresponds with previous observations and with the theoretical assumption that stable categorical (and under some conditions associative) relations stored in long-term memory are the major sources for semantic interference effects. The following experiment tested whether semantic interference effects for thematic relations can be induced by creating ad hoc relations between objects.

## Experiment 2

In this experiment the same objects and blocking conditions were used as in Experiment 1. However, here, title words were presented before the blocks started. The words were visually presented once before each set and referred to the category in the categorically homogeneous condition (e.g., title: “foods”; objects: *coffee*, *milk*, *fish sticks*, etc.) or to the common theme in the thematically homogeneous condition (e.g., title: “fishing trip”; objects: *coffee*, *bucket*, *stool*, etc.). Different unrelated titles were presented in the heterogeneous condition (see Appendix A). Titles preceding blocks of stimuli have been successfully used in other domains to manipulate, for example, difficulty of task, by suggesting an organizational structure for a block of stimuli (e.g., Fletcher, Shallice, & Dolan, 1998). Hence, we assume that participants will similarly use titles presented before picture blocks to structure and interrelate the objects along the specified dimension. If semantic activation and the resulting lexical competition are flexible and adjustable to the specific context, semantic interference should be observed not only for categorical relations but also for highlighted thematic relations.

## Method

**Participants.** Fourteen women and 10 men, aged 17 to 43 years ( $M = 24$ ), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All were native German speakers and reported normal or corrected-to-normal visual accuracy and normal color vision. None of the participants took part in the previous experiment. One participant was excluded and replaced because of high error rates.

**Materials, procedure, and design.** All details of the materials, procedure, and design were identical to those of the previous experiment except that here, title words were presented before the blocks started (see Appendix A). The titles were visually presented words that were shown for 5 s in the middle of the screen. Each title was shown only once before each set; the subsequent six presentations of the objects within each set were not preceded by a title. For the categorically and thematically homogeneous conditions the titles matched the semantic category (e.g., title:

<sup>2</sup> When the sphericity assumption was violated, the respective Huynh-Feldt  $\epsilon$  values for correction of degrees of freedom are reported together with the uncorrected degrees of freedom and the corrected significance levels.



“foods”; objects: *coffee, milk, fish sticks*, etc.) or the theme that integrates the objects of a given set in a meaningful way (e.g., title: “fishing trip”; objects: *coffee, bucket, chair*, etc.). For the heterogeneous condition a set of 10 different unrelated titles was chosen (five titles referred to categories, e.g., “clothing,” and five titles referred to themes, e.g., “tennis tournament”; see Appendix A). From this set, five different titles were randomly chosen and assigned to the five different heterogeneous blocks for each participant individually. Participants were informed that words would be presented before the naming blocks started and were instructed to read the words carefully. The experimenter did not mention potential relations between the words and the objects in the sets.

## Results and Discussion

Table 2 presents the mean RTs for correct naming trials, standard errors, and mean percentages of errors in the three experimental conditions, separately for the six stimulus repetitions, and collapsed across Presentations 2 to 6 (see also Figure 1). We discarded 3.1% of the trials.

The ANOVA yielded a main effect of semantic blocking,  $F_1(2, 46) = 9.1$ ,  $MSE = 711$ ,  $p < .001$ ;  $F_2(2, 48) = 11.9$ ,  $MSE = 556$ ,  $p < .001$ . Planned comparisons revealed an effect of semantic blocking for categorical relations,  $F_1(1, 23) = 14.0$ ,  $MSE = 1,799$ ,  $p < .001$ ;  $F_2(1, 24) = 22.3$ ,  $MSE = 1,133$ ,  $p < .001$ , and an effect for thematic relations,  $F_1(1, 23) = 4.4$ ,  $MSE = 1,350$ ,  $p < .05$ ;  $F_2(1, 24) = 8.9$ ,  $MSE = 695$ ,  $p < .01$ , demonstrating that categorical as well as thematic blocking induced a robust semantic interference effect. This is in clear contrast to Experiment 1, where no sign of interference was observed for thematic relations.

The critical finding of Experiment 2 was the observation of a semantic interference effect induced by thematic contexts. Although no such effect was found in Experiment 1, this result suggests that the dynamics of activation spread throughout the lexical network can be shaped flexibly simply by presenting a context word that integrates the otherwise unrelated objects. Interestingly, even the existing and well-established categorical relations seemed to benefit somewhat from the titles, suggesting that the gating can even amplify the saliency of entrenched taxonomic categories.

However, a combined analysis of Experiments 1 (without titles) and 2 (with block titles) confirms these conclusions only in part. The interaction of semantic blocking and group failed to reach

significance in the subjects analysis,  $F_1(2, 92) = 1.6$ ,  $MSE = 586$ ,  $p = .20$ , but did reach significance in the items analysis,  $F_2(2, 48) = 6.1$ ,  $MSE = 117$ ,  $p < .01$ . Planned comparisons revealed a similar picture. For categorical relations as well as for thematic relations, the interaction of semantic blocking and group reached significance in the items analyses,  $F_2(1, 24) = 10.9$ ,  $MSE = 451$ ,  $p < .003$ ;  $F_2(1, 24) = 8.0$ ,  $MSE = 450$ ,  $p < .009$ , respectively, but not in the subjects analyses,  $F_1(1, 46) = 2.3$ ,  $MSE = 1,459$ ,  $p = .13$ ;  $F_1(1, 46) = 2.2$ ,  $MSE = 951$ ,  $p = .14$ , respectively. Furthermore, even though thematically induced interference effects were present in Experiment 2 and absent in Experiment 1, the numerical differences between corresponding conditions in the two experiments was biggest in the heterogeneous conditions ( $M_{diff}$  for Presentations 2 to 6 = 15 ms). Such direct numerical comparisons between groups of subjects are hard to interpret because they can be due to many potential differences between participants, but ideally, the biggest difference should be found in the thematically homogeneous, not in the heterogeneous, conditions.

Our interpretations of the RT pattern across Experiments 1 and 2 in terms of flexible context adaptations are thus complicated by two aspects. First, the numerical differences between groups do not support our idea of a selective change in the thematic blocks. Second and related, the between-experiments interactions were significant in the items but not in the subjects analyses. We believe that this comparison may have been compromised by larger than expected levels of between-subjects variability in all experiments. When examining the pattern produced by each individual in Experiment 2, we observed that not everyone responded to the block titles in the same way. For a minority of participants, it appears that the block titles were not sufficiently meaningful or familiar to induce the adaptations needed to support lexical competition. Conversely, some participants in Experiment 1 may have been aware of the relation between the objects in the thematically homogeneous blocks even without title words. Therefore, the greater variability between participants within the experiments may have weakened the between-subjects comparison. In line with this interpretation, the by-items analysis did reveal robust interactions with experimental group. Across items, there may be less variability and thus a more stable effect of the context manipulation than across participants.

To summarize, despite the emergence of thematically induced semantic interference effects in Experiment 2, we did not find

Table 2  
Descriptive Data for the Semantic Blocking Conditions and Repetitions in Experiment 2

Repetition	Categorically homogeneous			Thematically homogeneous			Heterogeneous		
	RT	SE	Err	RT	SE	Err	RT	SE	Err
1	717	24.2	4.0	710	14.8	5.2	727	20.6	5.3
2	642	17.6	3.3	628	18.2	2.0	612	15.1	3.0
3	636	17.6	2.3	628	19.6	1.8	617	17.3	2.0
4	638	21.1	2.3	624	17.1	2.0	599	15.0	1.7
5	642	20.5	1.8	617	17.5	1.5	605	16.5	1.8
6	640	19.4	2.2	617	15.8	2.2	602	15.2	1.5
Mean of 2–6	640	19.2	2.4	623	17.6	1.9	607	15.8	2.0

Note. Mean naming latencies (reaction time [RT], in milliseconds), standard errors of the mean (SE), and mean percentage of errors (Err) are shown for the semantic blocking conditions and repetitions in Experiment 2.

unequivocal evidence for ad hoc thematically induced interference effects in Experiments 1 and 2. Therefore, the following experiments tested for such effects with a new and optimized set of materials (to facilitate the creation of thematically related sets, we excluded the categorically homogeneous condition in the remaining experiments). In Experiment 3 the new objects were named in thematically homogeneous or heterogeneous blocks. In the first part (Experiment 3A, corresponding to the procedure in Experiment 1), the blocks were presented without title words. In the second part (Experiment 3B, corresponding to the procedure in Experiment 2), all blocks were presented again, preceded by matching title words in the thematically homogeneous condition and by unrelated titles in the heterogeneous condition. Thus, ad hoc semantic interference effects were investigated with a within-subjects design. Furthermore, Experiment 4 was conducted with a different group of participants analogously to Experiment 2 (with matching title words in the homogeneous condition and unrelated words in the heterogeneous conditions). Both experiments were conducted in parallel, and participants were randomly assigned to Experiment 3 or 4.

### Experiment 3

The aim of this experiment was two-fold. First, we aimed to test for ad hoc interference effects within participants. This was done by first presenting the homogeneous and heterogeneous blocks without preceding title words, followed by the presentation of the same blocks preceded by matching or unrelated titles in the homogeneous and heterogeneous conditions, respectively.

The second aim was to find evidence for ad hoc thematically induced interference effects with a new set of materials that is less prone to between-subjects variability in responding to the context manipulations with and without title words. The selection of the new material was based on a two-step rating procedure that allowed us to select thematic relations and associated objects that appear unrelated for a high percentage of participants and that are viewed as meaningfully related within the given theme when title words are presented. As an additional control for intersubject variability, we included separate ratings after the first and second parts of the experiment, corresponding to the conditions without and with title words, respectively. The orthogonal manipulation of categories was dropped in order to optimize the materials in terms of thematic relations.

### Method

**Participants.** Twenty women and 12 men, aged 18 to 41 years ( $M = 23$ ), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All were native German speakers and reported normal or corrected-to-normal visual accuracy and normal color vision. None of the participants took part in the previous experiments.

**Materials.** A two-step rating procedure with nine participants (seven women and two men; none participated in the previous experiments) was conducted as follows. In a first rating, participants saw nine different sets of five thematically related objects (with the object names printed below each object). They were instructed to write down whether or not there was any meaningful relation between the five objects of each set and to rate the

interobject relatedness on a 5-point Likert scale from  $-2$  (*no relation*) to  $2$  (*highly related*). Participants were informed that only some or none of the sets contained objects that were meaningfully related and that the number of related sets would vary randomly between participants. This was done to avoid excessive searches for meaning relations. Furthermore, they were asked to indicate any objects deviating from within-set relations. Subsequently the same sets were presented again, this time with thematic title words printed above. Participants were instructed to read the words and to rate interobject relatedness within the denoted theme. Again, participants were asked to indicate any deviating objects within the themes. The best five object sets with maximal differences between Rating 1 ( $M = -1.1$ ) and Rating 2 ( $M = 1.3$ ) were selected ( $M_{\text{diff}} = 2.4$ ,  $SD = 0.5$ ). Finally, two objects that were consistently rated as not belonging to a given theme in the second rating were replaced. The new materials are presented in Appendix B.

**Procedure and design.** In the first part (Experiment 3A), participants named the objects in thematically homogeneous and heterogeneous conditions. Just like in the previous experiments, all objects were named six times in each condition. In the second part (Experiment 3B), the identical procedure was repeated except that here, title words were presented before the blocks started (analogously to the procedure in Experiment 2). Thus, all objects were named 12 times (six times in the homogeneous and six times in the heterogeneous conditions) in the first part and 12 times in the second part of the experiment. In the first part the order of the blocking conditions was counterbalanced across participants; the order of different blocks within the homogeneous and heterogeneous conditions was randomized for each participant individually. The same procedure was repeated in the second part.

After the first and second parts of the experiment, a rating was conducted in which participants saw all thematically homogeneous and heterogeneous sets of objects (with their names printed below but without titles) and rated the interobject relatedness within each homogeneous and heterogeneous set on a scale from  $-5$  (*no relation*) to  $5$  (*highly related*). All other details of the procedure and design were identical to those of Experiments 1 and 2.

### Results and Discussion

Table 3 presents the mean RTs for correct naming trials, standard errors, and mean percentages of errors in the two experimental conditions, separately for the six stimulus repetitions, and collapsed across Presentations 2 to 6 in Experiments 3A and 3B. Figure 2 presents the response latencies, and Figure 3 depicts the results of the interobject relatedness ratings conducted after each part of the experiment. We discarded 4.9% of the trials.

**Interobject relatedness ratings.** Mean relatedness ratings were submitted to ANOVAs with the within-subjects factors title words (Experiment 3A, without titles; Experiment 3B, with titles) and homogeneity (thematically related vs. unrelated sets). This analysis revealed highly significant main effects of title words,  $F_1(1, 31) = 52.7$ ,  $MSE = 3$ ,  $p < .001$ , and homogeneity,  $F_1(1, 31) = 71.8$ ,  $MSE = 3$ ,  $p < .001$ , and an interaction of title words and homogeneity,  $F_1(1, 31) = 55.2$ ,  $MSE = 2.6$ ,  $p < .001$ , reflecting an increase in the relatedness ratings for the thematically homogeneous sets in Experiment 3B (see Figure 3). Whereas there was no reliable difference between thematically related and unrelated sets in Experiment 3A,  $t(31) = 1.1$ ,  $p = .27$ , there was a

Table 3

*Descriptive Data for the Semantic Blocking Conditions and Repetitions in Experiment 3*

Repetition	Experiment 3A: No block title						Experiment 3B: Block title					
	Thematically homogeneous			Heterogeneous			Thematically homogeneous			Heterogeneous		
	<i>RT</i>	<i>SE</i>	<i>Err</i>	<i>RT</i>	<i>SE</i>	<i>Err</i>	<i>RT</i>	<i>SE</i>	<i>Err</i>	<i>RT</i>	<i>SE</i>	<i>Err</i>
1	654	9.9	8.8	656	12.4	7.9	637	8.9	4.5	634	9.2	5.0
2	587	9.3	4.5	588	10.1	4.4	592	9.8	3.9	583	8.3	3.5
3	576	9.0	5.4	575	9.8	3.9	584	10.4	3.9	576	7.8	3.3
4	573	9.5	5.0	571	8.9	3.5	589	9.2	2.9	573	10.2	3.9
5	574	9.3	5.1	571	9.1	4.4	584	9.8	3.5	573	9.1	2.4
6	568	10.2	5.9	569	9.0	3.5	579	10.1	4.1	575	10.5	3.1
Mean of 2–6	576	9.5	5.2	575	9.4	3.9	586	9.9	3.7	576	9.2	3.2

*Note.* Mean naming latencies (reaction time [*RT*], in milliseconds), standard errors of the mean (*SE*), and mean percentage of errors (*Err*) are shown for the semantic blocking conditions and repetitions in Experiment 3A (without block title) and Experiment 3B (with block title).

highly significant difference in Experiment 3B,  $t(31) = 11.1$ ,  $p < .001$ . These effects demonstrate that the title words successfully induced meaningful relations between objects that were viewed as unrelated by many participants without this context information.

**RTs.** The omnibus ANOVA including title words (present vs. absent) and semantic blocking condition (thematically related vs. unrelated) in the participants analysis revealed effects only approaching significance of title words,  $F_1(1, 31) = 3.4$ ,  $MSE = 304$ ,  $p = .07$ , and semantic blocking,  $F_1(1, 31) = 3.3$ ,  $MSE = 288$ ,  $p = .079$ , and no significant interaction of title words and blocking,  $F_1(1, 31) = 2.9$ ,  $MSE = 218$ ,  $p = .097$ . In contrast, all main effects and the interaction were significant in the items analyses,  $F_2(1, 24) = 112.7$ ,  $MSE = 116$ ,  $p < .001$ ;  $F_2(1, 24) = 5.4$ ,  $MSE = 211$ ,  $p < .05$ ;  $F_2(1, 24) = 6.0$ ,  $MSE = 67$ ,  $p < .05$ , respectively.

Just like in the between-groups analysis of Experiments 1 and 2, we found in this within-subjects comparison a robust modulation of semantic blocking effects by title words in the items analysis and a nonsignificant interaction in the analysis by participants. As discussed above, this is presumably due to high between-subjects variability in terms of whether the thematic relations were spontaneously recognized without titles. As an additional control for such variability we included interobject relatedness ratings that can be integrated in the statistical analyses. Both the initial ratings for the material selection and the numerical (albeit nonsignificant) difference between the ratings for thematically related and unre-

lated objects in Experiment 3A (without titles) suggested that not all participants may have been unaware of the thematic relations. Thus, when RTs were submitted to an analysis of covariance (ANCOVA) by participants, including the interobject relatedness ratings of Experiment 3A (when no titles were presented) as a covariate, we found a significant effect of title words,  $F_1(1, 31) = 4.9$ ,  $MSE = 285$ ,  $p < .05$ , whereas the main effect of blocking did not reach significance,  $F_1(1, 31) = 2.6$ ,  $MSE = 293$ ,  $p = .11$ . Most importantly, we found an interaction of title words and blocking,  $F_1(1, 31) = 4.2$ ,  $MSE = 205$ ,  $p < .05$ . Thus, when the intersubject variability was covaried out, title words successfully induced meaningful relations between the objects in the thematically homogeneous conditions. These conclusions were further confirmed by post hoc tests, yielding no effects of semantic blocking in Experiment 3A ( $t_s < 0.4$ ) and significant effects in Experiment 3B,  $t_1(31) = 2.8$ ,  $p < .01$ ;  $t_2(23) = 2.7$ ,  $p < .05$ .

As an aside, and in contrast to the group analysis of Experiments 1 and 2, the differences found here between blocking effects with and without titles can clearly be attributed to enhanced, albeit numerically small, interference effects in the thematically homogeneous condition with titles relative to the condition without ( $M_{\text{diff}} = 10$  ms),  $t_1(31) = 2.4$ ,  $p < .05$ ;  $t_2(24) = 3.3$ ,  $p < .01$ , whereas there was no such difference in the heterogeneous condition ( $M_{\text{diff}} = 1$  ms;  $t_s < 0.3$ ).

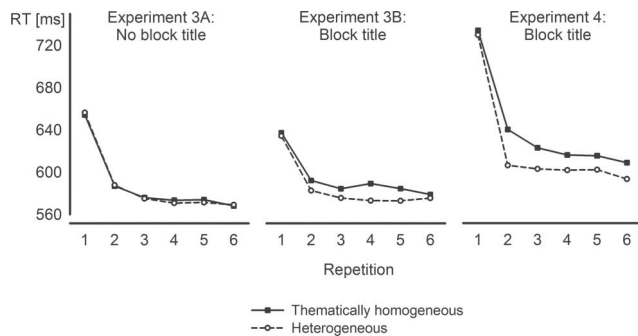


Figure 2. Mean blocking effects, separately for the six object repetitions, in Experiments 3A (left), 3B (middle), and 4 (right). RT = reaction time.

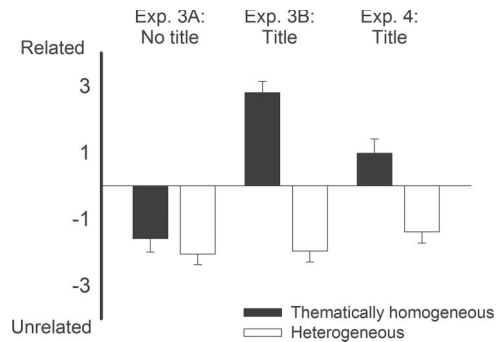


Figure 3. Ratings of interobject semantic similarity in Experiments 3A (left), 3B (middle), and 4 (right). Error bars depict standard errors of mean.



To summarize, here we found evidence for ad hoc induced semantic interference effects in a within-subjects design when the intersubject variability was covaried out. This is a remarkable finding because it demonstrates that (small) interference effects can be induced by title words even with objects that have repeatedly been named in thematically related blocks six times before—without any sign of such context effects. Experiment 4 complements these observations with a between-subjects design.

### Experiment 4

This experiment was conducted analogously to Experiment 2, testing for thematic interference effects induced by title words with the new materials described in the previous experiment. We expected to observe stronger interference effects than in the second part of the previous experiment because here the titles were presented directly and the objects were not named repeatedly before without titles, which should enhance the effects. Furthermore, with the new materials we expected more robust between-groups differences for the comparison of blocking effects with and without title words (Experiments 3A and 4) as observed in Experiments 1 and 2.

### Method

**Participants.** Twenty-three women and nine men, aged 19 to 65 years ( $M = 24$ ), were paid for their participation in the experiment or received partial fulfillment of a curriculum requirement. All were native German speakers and reported normal or corrected-to-normal visual accuracy and normal color vision. None of the participants took part in the previous experiments or ratings.

**Materials, procedure, and design.** All details of the materials, procedure, and design were identical to those of Experiment 3B.

### Results and Discussion

Table 4 presents the mean RTs for correct naming trials, standard errors, and mean percentages of errors in the two experimental conditions, separately for the six stimulus repetitions (see also Figures 2 and 3). We discarded 5.4% of the trials.

Table 4  
*Descriptive Data for the Semantic Blocking Conditions and Repetitions in Experiment 4*

Repetition	Thematically homogeneous			Heterogeneous		
	<i>RT</i>	<i>SE</i>	<i>Err</i>	<i>RT</i>	<i>SE</i>	<i>Err</i>
1	734	18.2	7.6	730	14.7	6.0
2	640	12.6	4.8	606	9.3	5.0
3	623	11.8	5.1	603	9.4	4.6
4	616	10.8	3.4	602	10.1	4.3
5	615	11.5	3.0	602	9.9	4.0
6	609	10.8	3.5	593	11.1	5.4
Mean of 2–6	621	11.5	4.0	601	10.0	4.7

*Note.* Mean naming latencies (reaction time [*RT*] in milliseconds), standard errors of the mean (*SE*), and mean percentage of errors (*Err*) are shown for the semantic blocking conditions and repetitions in Experiment 4.

**Interobject relatedness ratings.** The mean relatedness rating revealed a highly significant difference between homogeneous and heterogeneous sets of objects,  $t(31) = 5.6$ ,  $p < .001$ . A between-groups analysis (Experiment 3A without titles and Experiment 4 with titles) revealed main effects of homogeneity,  $F_1(1, 62) = 22.8$ ,  $MSE = 2$ ,  $p < .001$ , and group,  $F_1(1, 62) = 13.3$ ,  $p < .001$ , and an interaction of homogeneity and group,  $F_1(1, 62) = 10.3$ ,  $p < .01$ , confirming an increase in the relatedness ratings for the thematically homogeneous sets in Experiment 4 (see Figure 3).

**RTs.** The ANOVA yielded a highly significant main effect of semantic blocking,  $F_1(1, 31) = 17.5$ ,  $MSE = 342$ ,  $p < .001$ ;  $F_2(1, 24) = 27.8$ ,  $MSE = 163$ ,  $p < .001$ . This experiment thus replicated the observation of Experiment 2, a semantic interference effect for thematic relations in the context of title words. Although the interaction of blocking and group was not significant for Experiments 1 and 2, the combined analysis of Experiments 3A (without titles) and 4 (with block titles) yielded a significant main effect of semantic blocking,  $F_1(1, 62) = 10.0$ ,  $MSE = 330$ ,  $p < .01$ ;  $F_2(1, 24) = 14.6$ ,  $MSE = 192$ ,  $p < .001$ , and, most importantly for the present purpose, a significant interaction of semantic blocking and group,  $F_1(1, 62) = 8.1$ ,  $p < .01$ ;  $F_2(1, 24) = 31.6$ ,  $MSE = 56$ ,  $p < .001$ . This finding remains significant even if one adjusts the significance levels to account for the fact that the data from Experiment 3A were reused in this analysis.

### General Discussion

The aim of this study was to investigate dynamic aspects of semantic and lexical activation spread during speech planning. Research on semantic context effects has thus far focused on stable connections between concepts stored in long-term memory, such as categorical relations. Here, we move away from investigating hard-wired semantic relations to an investigation of more flexible and context-specific semantic adaptations during lexicalization.

We explored whether interference effects in the blocking paradigm can be induced by manipulations of ad hoc contexts in which the utterance is produced. The presentation of title words that establish thematic relations between objects within a naming set was accompanied by interference effects (Experiments 2, 3B, and 4) that were not observed when no title words were presented, leaving the thematic relation between the objects opaque (Experiments 1 and 3A).

Not surprisingly, we also observed that the effects of ad hoc induced thematic relations were not as strong and robust as classic categorically induced interference effects. In particular, even though we observed interference effects systematically only in the presence of title words throughout the series of experiments—and found no sign of such effects when no titles were presented—some comparisons were statistically not reliable. Specifically, the comparison between Experiment 1 (without titles) and Experiment 2 (with titles) was significant in the analysis by items but not by participants. We argue that these comparisons may have been compromised by larger than expected levels of between-subjects variability in the processing of thematic relations. This interpretation gained support when we included interobject relatedness ratings in the statistical analyses of Experiment 3, revealing significant interactions of semantic blocking and title words when the initial individual differences in the processing of thematic relations were covaried out. Indeed, it is remarkable that ad hoc interference

effects could be observed in Experiment 3B, given that the thematic blocking had no effect across six presentations before the titles were introduced.

Together with the strong interference effects observed in Experiment 4 and the general lack of evidence for thematically induced semantic interference effects in the speech production literature, these findings suggest that semantic activation spread during speech planning can be modulated and flexibly adapted as a given context or situation dictates. Furthermore, the conceptual flexibility impacts lexical selection processing by modulating the activation levels of competitors. Whether categorically and associatively unrelated objects such as *bucket* and *knife* interfere with each other depends on whether they are interrelated, and thus integrated, by an ad hoc formation of a thematic category (Experiments 2, 3B, and 4) or not (Experiments 1 and 3A).

Taken together, the results demonstrate that the automatic process of activation spread is sensitive to dynamic adaptations modulated by attention, intentions, goals, and situations. In line with the gating framework proposed by Kiefer (2007), we suggest that the block titles induce preemptive control on the spread of activation. By directing attention to the theme denoted by the context label, activation to relevant concepts is amplified. It is already well attested that the automatic semantic processes associated with word and number processing are sensitive to top-down attentional control derived from intentions, goals, task set, and so forth (Barsalou, 1993, 2007). The present study demonstrates that these adaptations within the semantic system occur during picture naming by modulating lexicalization processes.

In addition to supporting the well-established notion of dynamic and flexible semantic activation flow, the present results speak to the source of semantic interference effects during single word production. Recently, Abdel Rahman and Melinger (2009a, 2009b) proposed an extension of competition models of lexical selection. In most competitive models, the time needed to select a target lemma from the set of active lemmas is sensitive to the activation level of the competitors. The involvement of competition in lexical selection processes has been challenged by observations that non-categorical relations, such as associative relations, part-whole relations, and thematic relations, fail to produce interference effects in the influential PWI paradigm (Alario et al., 2000; Bólte et al., 2003; Costa et al., 2005; La Heij et al., 1990; Lupker, 1979).<sup>3</sup> Abdel Rahman and Melinger suggested that the principle of competition could account for those findings if competition was calculated on the basis of the activation level of the entire lexical network rather than against the nearest competitor and if the activation of the lexical system was sensitive to dynamic changes in the semantic system. Here, we have presented support for this latter assumption. Our results demonstrate that lexical selection processes, and the related semantic interference, are sensitive to dynamic context-induced changes to the weights linking objects.

Likewise, integrating the notion of contextually sensitive flexible and dynamic activation spread at the conceptual level into other competitive models of lexical selection should be sufficient to enable them to account for the present results as well (e.g., Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Oppenheim, Dell, & Schwartz, 2010). For example, Howard et al. (2006) argued that three principles are required to account for the semantic interference effects they observed using a noncyclic variant of the semantic blocking paradigm: (a) activation spread at the con-

ceptual level, (b) lexical competition, and (c) priming. Extending the ways in which activation is allowed to spread at the conceptual level should essentially bring this model in line with the data reported here.

In our experiments, when no context word preceded thematically homogeneous blocks, the relations between the objects were insufficiently salient to produce mutually beneficial semantic activation, resulting in levels of lexical activation similar to what is typically observed in heterogeneous naming blocks. In other words, because the objects were not obviously related to one another, they did not reinforce each other's conceptual and lexical level of activation. This resulted in a set of weakly activated lexical competitors that did not strongly influence target selection time. In contrast, when a context was provided that established a common thread between the elements, suddenly significant interference was observed. Following the logic outlined by Abdel Rahman and Melinger (2009a, 2009b), this emergence is due to the dynamic adaptations that occur in response to processing the objects following the context title. Because the congruent titles serve to bind the objects together into a meaningful context, mutually beneficial activation spread can be achieved, giving rise to a more competitive lexical network. As was suggested by Abdel Rahman and Melinger (2007, 2009b), convergent activation spread can produce category-like interference for noncategorical relations. Thus, activation gating at the semantic level mediates the amount of activation and competition observed lexically.

To summarize, the current experiments revealed highly flexible and adaptive aspects of semantic and lexical activation spread well beyond hard-wired structures stored in long-term memory, aspects that have thus far been largely neglected in research on speech production. What remains to be determined is whether interference can also be induced for items that are even more loosely related. Although the thematic objects presented here had no obvious categorical or associative links (which was confirmed in Experiments 1 and 3A), they were nevertheless not entirely unrelated. The key word "fishing trip" did activate a combination of objects that have, within this thematic context, semantic links that are stored in long-term memory. Thus, future research should address the scope and potential limits of flexible context adaptations of the system.

<sup>3</sup> Super- and subordinate relations in the picture-word paradigm produce equivocal effects, sometimes revealing interference (Glaser & Döngelhoff, 1984; Hantsch, Jescheniak, & Schriefers, 2005; Kuipers, La Heij, & Costa, 2006, Experiments 1A and 1B) and other times producing facilitation (Costa, Mahon, Savova, & Caramazza, 2003; Glaser & Döngelhoff, 1984; Kuipers et al., 2006, Experiment 3; Vitkovitch & Tyrrell, 1999).

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(Appendices follow)



## Appendix A

### Material Used in Experiments 1 and 2

Title (used only in Experiment 2)		Words			
Categorically homogeneous condition					
Lebensmittel (food)	Kaffee (coffee)	Milch (milk)	Fischstäbchen (fish sticks)	Butterbrot (sandwich)	Reis (rice)
Werkzeuge (tools)	Messer (knife)	Waage (scale)	Zirkel (compass)	Verbandskasten (first aid kit)	Kamera (camera)
Behälternisse (bins)	Eimer (bucket)	Korb (basket)	Brotdose (lunchbox)	Tasche (bag)	Geschenkkarton (gift box)
Mobiliar (furnishings)	Stuhl (stool)	Regal (shelf)	Tafel (blackboard)	Fußmatte (mat)	Altar (altar)
Orte (locations)	Bach (creek)	Parkplatz (parking lot)	Spielplatz (playground)	Werkstatt (garage)	Zelt (marquee)
Thematically homogeneous condition					
Angeln (fishing trip)	Kaffee (coffee)	Messer (knife)	Eimer (bucket)	Stuhl (stool)	Bach (creek)
Supermarkt (supermarket)	Milch (milk)	Waage (scale)	Korb (basket)	Regal (shelf)	Parkplatz (parking lot)
Grundschule (elementary school)	Fischstäbchen (fish sticks)	Zirkel (compass)	Brotdose (lunchbox)	Tafel (blackboard)	Spielplatz (playground)
Autoreise (car journey)	Butterbrot (sandwich)	Verbandskasten (first aid kit)	Tasche (bag)	Fußmatte (mat)	Werkstatt (garage)
Hochzeit (wedding)	Reis (rice)	Kamera (camera)	Geschenkkarton (gift box)	Altar (altar)	Zelt (marquee)
Heterogeneous condition					
	Bach (creek)	Tafel (blackboard)	Reis (rice)	Verbandskasten (first aid kit)	Korb (basket)
	Butterbrot (sandwich)	Kamera (camera)	Eimer (bucket)	Regal (shelf)	Spielplatz (playground)
	Fischstäbchen (fish sticks)	Messer (knife)	Altar (altar)	Parkplatz (parking lot)	Tasche (bag)
	Werkstatt (garage)	Milch (milk)	Zirkel (compass)	Geschenkkarton (gift box)	Stuhl (stool)
	Kaffee (coffee)	Waage (scale)	Brotdose (lunchbox)	Fußmatte (mat)	Zelt (marquee)

*Note.* Title words for the heterogeneous condition were as follows: Schmuck (jewelry), Kleidung (clothing), Körperteile (body parts), Pflanzen (plants), Tiere (animals), Arztbesuch (consultation), Tennisturnier (tennis tournament), Einsame Insel (desert island), Museum (museum), and Wanderung (hike).

(Appendices continue)

## Appendix B

### Material Used in Experiments 3 and 4

Title (used only in Experiments 3B and 4)		Words			
Thematically homogeneous condition					
Beerdigung (funeral)	Schaufel (shovel)	Taschentücher (handkerchiefs)	Blumen (flowers)	Anzug (suit)	Kaffee (coffee)
Flohmarkt (flea market)	Tisch (table)	Stiefel (boots)	Puppe (doll)	Geldkassette (cash box)	Buch (book)
Wanderung (hike)	Socke (socks)	Pflaster (plaster)	Müsliriegel (cereal bar)	Löwenzahn (dandelion)	Bussard (buzzard)
Zoobesuch (zoo)	Seile (ropes)	Nest (nest)	Lama (llama)	Knochen (bone)	Eis (ice cream)
Wahlkampf (campaign)	Schirm (sunshade)	Videokamera (video camera)	Luftballon (balloon)	Kuli (pen)	Rednerpult (podium)
Heterogeneous condition					
	Schaufel (shovel)	Geldkassette (cash box)	Pflaster (plaster)	Nest (nest)	Videokamera (video camera)
	Anzug (suit)	Buch (book)	Löwenzahn (dandelion)	Eis (ice cream)	Schirm (sunshade)
	Blumen (flowers)	Tisch (table)	Socke (socks)	Knochen (bone)	Luftballon (balloon)
	Taschentücher (handkerchiefs)	Stiefel (boots)	Müsliriegel (cereal bar)	Lama (llama)	Kuli (pen)
	Kaffee (coffee)	Puppe (doll)	Bussard (buzzard)	Seile (ropes)	Rednerpult (podium)

*Note.* Title words for the heterogeneous condition were as follows: Museum (museum), Tennisturnier (tennis tournament), Spielplatz (playground), Autoreise (car journey), and Arztbesuch (consultation).

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